CHAPTER 6 – HMA INSPECTION
(QC Technician and DOTD Inspector)

The concept of applying a payment adjustment to certain acceptance tests does not imply that the role of the DOTD Certified Plant Inspector is limited to performing or monitoring these tests. Increased dependence on contractor/producer quality control programs has extended the need for DOTD inspectors to be knowledgeable and vigilant concerning the production, transport, placement and compaction of hot-mix asphalt materials. It is intended that the contractor and mix producer adhere to all requirements of the specifications, not merely those to which payment adjustments may be applied.

Subsections 501.12(a) and 502.12(b)(1), Acceptance Requirements, of the *Standard Specifications* require department personnel to visually inspect the HMA product. Certified inspectors are to evaluate the mixture both at the plant and at the jobsite. Mixtures exhibiting deficiencies before placement, such as segregation, contamination, lumps, nonuniform coating, excessive temperature variations or other deficiencies shall not be placed. Mixture contamination, alignment deviations, variations in surface texture and appearance or other deficiencies apparent on visual inspection will not be accepted. Poor construction practices such as inadequate handwork, improper joint construction or other deficiencies apparent on visual inspection will also not be accepted. Deficiencies revealed by visual inspection, both after placement and before final acceptance, shall be corrected at the contractor's expense.

The Certified Plant Inspector and the Certified Paving Inspector are the official representatives of the department through the authority of the project engineer. Hence, the project or plant becomes the inspector's responsibility. Other department representatives must coordinate their efforts to improve operations within the realm of their responsibility with the Certified Inspector at the plant or project site.

If problems arise in production, transport or paving operations, it is the Certified Inspector's responsibility to notify the contractor/producer's representatives that the product is not meeting department standards. The DOTD Certified Inspector will tell the contractor/producer what is wrong, but under no circumstances is the inspector to order a solution to the problem by word or action. Correcting the problem so that the product meets all requirements of the specifications is the responsibility of the contractor/producer. The inspector is to notify the proper personnel and make a subsequent investigation to ensure that successful corrective action has been taken. The inspector will document all actions, discussions with other department personnel and contractor/producer personnel, any other information relevant to the situation and will take measurements or samples, as necessary, to identify the problem.

When deficiencies occur in any area of the production, transport or paving processes, the contractor/producer must take immediate action to correct the problem. Failure to do so can result in the discontinuance of operations for DOTD projects. Product control shall be accomplished by a program independent of, but correlated with, the department's acceptance testing and shall verify that all requirements of the JMF are being achieved, and that necessary adjustments provide specification results. The existence of payment adjustment schedules for failure of the product to be in complete compliance with department standards in some areas, does not imply that standards for which less than 100% of the contract unit price will be paid are considered acceptable by the department. **It is the intent that those standards for which 100 percent pay is provided be met for all production. Whenever the mixture produced falls into areas under which payment adjustment schedules must be applied, the contractor/producer shall make immediate adjustments or the DOTD Certified Inspector will require the discontinuance of operations for DOTD projects.**

The inspection of the HMA product must be a coordinated effort between the plant and paving inspectors. Because problems in the laydown phase of the operation may be directly related to mix characteristics, the paving Inspector is to confer with the plant inspector regarding problems that may originate in the manufacturing process.

PLANT INSPECTION

The Certified Inspector at the plant must continually observe the entire manufacturing process. The inspector is to make a daily general inspection of the plant to ensure that it is in conformance with the standards under which certification was granted. The inspector must be familiar with Section 503 of the *Standard Specifications*, Asphaltic Concrete Equipment and Processes, and the certification standards for plants. It is also the inspector's responsibility to observe QC testing, monitor the results, and perform any sampling and testing operations assigned to department personnel.

The following headings indicate areas of the plant in which routine inspection is considered essential. These lists are not intended to be comprehensive or to exclude other areas from regular inspection. They are merely intended to serve as a guide to the inspector in the performance of this responsibility.

Stockpiles and Handling – Any new materials delivered to the plant are to be inspected, sampled and tested in a timely manner so that production is not disrupted. Aggregates must be handled in a manner that will not be detrimental to the final mixture. Stockpiles shall be built without causing segregation. Segregation can be minimized if stockpiles are constructed in successive layers, not in a conical shape. Constructing stockpiles in layers enables the tendency of large aggregates to roll to the outside and bottom of the pile. Stockpiles shall be located on a clean, stable, well-drained surface to ensure uniform moisture content throughout the stockpile. The area in which the stockpiles are located shall be large enough for the stockpiles to be separated, so that no intermixing of materials will occur. Stockpiles shall not become contaminated with deleterious materials such as clay balls, leaves, sticks or non-specification aggregates.

Cold Bins – Cold feed bins shall be inspected routinely. They shall be of the proper size to accommodate loader bucket size and plant production. They shall also be of a configuration that will not contribute to segregation and be in good condition. There shall be no holes in any bin. The automatic system used to control the proportioning system shall be equipped with alarms that will indicate whenever any aggregate bin becomes empty or flow is interrupted. Bins shall be separated by partitions extending a minimum of one foot above the bin top so that no intermixing of materials can occur. The partitions shall not be worn or broken. If a partition is damaged to the point that this specification is not met, the contractor/producer shall replace the damaged part. Cold feed bins shall be loaded in a manner that will not contribute to segregation. Aggregates shall be dumped into the center of each bin. Bins shall be kept adequately filled with a relatively constant level of material with uniform moisture content.

All plants, for certification, are required to have a screen (or scalping system) on the fine sand cold bin and other bins, as necessary, to ensure removal of objectionable material.

When a belt scale is used, an additional vibrating scalping screen is required between the aggregate cold feed discharge and the belt scale. Should the plant be equipped with no belt scale, a vibrating scalping screen shall be required between the cold feed discharge and the mixing process. In either case, the screens shall be sized to remove any oversize material and other objectionable material. All screens shall be in good condition, clean, not worn excessively, with no broken wires or holes. All scalping screens must be sufficiently small to ensure removal of all oversize aggregate.

Belt feeders shall be in good condition, not worn or broken. Gate openings and belt speeds shall be set to distribute the appropriate gradation for the job mix formula being produced. The gate openings and belt speeds shall be periodically inspected to ensure that they remain properly set. Aggregates shall flow uniformly onto the belt. Clogged gates, bridging or excessive moisture can cause nonuniform flow. If the material is not flowing uniformly, the inspector will require the contractor/producer to locate and correct the problem.

Further, the opening for each bin shall be rectangular, with one dimension adjustable by positive mechanized adjustment with a locking system. Indicators shall be provided on each gate to show the gate openings in inches.

Plant Equipment – The plant equipment and operations are to be inspected continually during production to ensure that no malfunctions have occurred that will have a detrimental effect on the mixture. The inspector is to observe the loading of trucks to ensure that loading techniques or discharge equipment is not contributing to mixture segregation. Equipment that drops a large amount of mixture at a time into the truck will tend to generate less segregation than equipment that discharges a small flow/stream. Discharging material into the front, back, then middle of the truck bed is a sequence that should be utilized at the plant to load trucks. The material dropped into the front and back should be placed as close as possible to the front and back of the bed to minimize segregation caused by the rolling of large aggregates.

The intent of this truck loading procedure is to minimize the roll down of coarse aggregate at the front and back of the truck and to concentrate any roll down in the center of the load, where it will be more readily mixed with the mass of material during discharge into the paver. When equipment necessitates deviating from this procedure, the producer may modify this procedure as long as segregation does not occur.

Batch plants will be checked during production for such things as proper sequence of bin use, screens, uniform asphalt cement distribution, proper mixing temperature, leaking valves or gates, JMF mixing time, excessive override, overflow chutes not blocked and no dry material falling into truck beds during loading.

Drum mix plants will be checked for satisfactory performance by inspecting the material exiting the drum mixer. It will be checked for temperature, coating (Ross Count, if questionable), moisture and segregation. If segregation is occurring during the mixing process, one side of the material coming out of the dryer/drum will usually be fine and the other coarse. Such segregation is often caused by improper drum operation.

Material produced at the beginning or termination of production periods shall be diverted from DOTD projects. The QC technician shall observe the mixture coming out of the diversion apparatus during these periods to determine that proper mixing and coating are being achieved before allowing the HMA materials to enter the surge or storage silos.

The slat (or bucket) conveyor must be checked for overload. If the conveyor is overfilled, causing large aggregates to accumulate in pockets, the conveyor is overloaded. The speed of the conveyor system or plant production must be adjusted. Overload will cause segregation. The speed of the slat conveyor must be coordinated with the plant's production rate. Material shall drop vertically into the silo.

The surge or storage silos in use at all plants are components that must be carefully and routinely inspected. The slug feeder on the top of the silo must operate properly and at all times. The gates must close tightly so that material cannot dribble through. The required indicator lights in the control room must accurately reflect how long the slug feeder is open. The silo or surge silo must be kept at least one-third full at all times to maintain the proper cone shape of the material in storage and to reduce the height of mix drop, thereby helping to prevent segregation.

Scales and Meters - The Weights and Measures Division of the Louisiana Department of Agriculture or an approved independent scale service must calibrate the scales and meters at the plant every ninety days. There must be a calibration sticker on each scale and meter. If the inspector has reason to question the calibration of any scale or meter, the inspector will contact the district laboratory engineer. The district laboratory engineer has the authority to require the recalibration of scales or meters even though the ninety-day calibration sticker has not expired. Meters must properly display flow rate and total amount of material/liquid dispensed.

HMA Mixtures

Temperature of the HMA Mixture – The temperature is to be checked a minimum of 5 trucks per lot by the QC technician and recorded on the QA copy of the Asphaltic Concrete Plant Report. For each temperature determination, the temperature shall be checked in more than one location per truck.

Segregation – HMA mixtures that exhibit obvious segregation when loaded at the plant shall not be issued a haul ticket. The material shall not be transported to a DOTD project. If segregation is a problem at the plant the loading procedure, stockpile construction, cold feed bin operation, mixing process and surge/storage bin operations should immediately be inspected for proper function.

Uniformity – The HMA material should be uniform in appearance in all aspects from batch to batch and from one area of the truckload to another. There should be no lumps, areas of differing color, segregation or wet/dry areas.

Color (Odor) – The HMA material should be uniform in color. Color deficiencies or odor may be indicative of oxidized asphalt cement. Inconsistent color throughout a truckload may also be the result of excessive dryer/drum flight wear, low or excessive asphalt cement content or inadequate drying/heating. If the mixture does not exhibit acceptable uniform color, the inspector will require the QC technician to identify and correct the problem.

Asphalt Coating – HMA material which exhibits obvious coating deficiencies shall not be transported to a DOTD project. If the inspector determines that the mixture is improperly coated, he/she will sample the deficient material and perform a Ross Count (AASHTO T 195) to determine the degree of deficiency and to determine if the material meets the DOTD requirements of 95 percent coating.

Moisture – Excess moisture in HMA materials may cause the mixture to appear to have excessive asphalt cement. Hence, the material will appear to be wet and shiny looking and slump in the truck. This is because, prior to the evaporation of some of the moisture, the saturated steam is acting like excess asphalt cement. In reality, the material may even lack sufficient asphalt cement to achieve a proper bond. If the Certified Inspector(s) suspects moisture problems, then the HMA material shall be analyzed for moisture content (TR 319). **The maximum moisture content allowed by specifications is 0.5 percent.**

Haul Trucks – DOTD inspectors will routinely inspect trucks to ensure they are clean and that there are no holes in the trailer beds. Materials shall not be allowed to build up in truck beds. Truck beds must be coated with an approved mix release agent, as needed. Neither diesel nor any other petroleum based product shall be used as a mix release agent. Each truck shall have an adequate cover and tie downs. The cover must be in good condition with no holes or tears and must cover the complete bed. Covers shall be used to protect the material from rain and excessive temperature loss. **All haul trucks shall have silver weight certification stickers attached to the cab and the trailer unit (Appendix M). These two stickers must match to be valid. If the weight certification stickers are not valid, project personnel are to notify the district laboratory engineer and proceed in accordance with EDSM III.1.1.12 (Appendix L).**

PAVING INSPECTION

The Certified Paving Inspector at the laydown site is responsible for observing surface tolerance testing and taking immediate possession of the profile trace when rideability testing is performed by the contractor, An authorized profilograph operator will perform rideability testing the department when the department conducts independent acceptance testing for surface tolerance. The inspector is also responsible for checking lane widths and other grade and alignment checks and equipment suitability. In addition, the inspector is responsible for maintaining a running total of tonnage delivered to the project from each plant production lot. The inspector must also mark the beginning and ending limits of each lot as it is placed on the roadway. Continuous records of lot placement should be maintained in a field book. The paving inspector will check yield on a continuing basis during the project and calculate it for each portion of a lot delivered to the roadway. Beyond these duties, the paving inspector must observe the appearance of the mat behind the paver and the rollers, the uniformity and acceptability of joint construction and the performance of the paving train equipment. If material related problems occur at the jobsite, then the paving Inspector shall make immediate contact with the Certified Plant Inspector so that adjustments can be made in the manufacturing and transport processes.

The following headings indicate areas of the paving operation in which routine inspection is considered essential. This list is not intended to be comprehensive or to exclude any other area from regular inspection. It is merely intended to serve as a guide to the field inspector in the performance of this responsibility. It is particularly important that the guidelines regarding the inspection of compaction be implemented.

Paving Equipment - Asphalt distributors, pavers, and rollers will be certified by the district laboratory. All certified equipment must be maintained in good working condition and continue to meet the standards under which certification was issued.

The contractor must have adequate incidental equipment such as rakes, tamps, lutes and shovels for the work being performed available at the project. This equipment must be clean and in satisfactory condition.

The inspector is to check rollers routinely for conformance to specification and certification requirements. All scrapers and watering systems shall be in good condition and functioning properly. Steel wheels will be checked for flat spots. All tires on pneumatic rollers shall be of the same size and ply rating. The air pressure of each tire shall be within ± 5 psi.

Subsection 503.10 of the *Standard Specifications* requires the use of a material transfer vehicle (MTV) when placing the final two lifts of HMA on roadway travel lanes. The MTV delivers HMA materials directly from the hauling equipment to the paving equipment. The MTV is required regardless of average daily traffic (ADT). The MTV shall perform additional mixing of the HMA materials, and then deposit the material in the paving equipment hopper to reduce segregation.

As a minimum, the MTV shall have the following:

- A high capacity truck unloading system that will receive materials from the hauling equipment; a storage bin in the MTV to continuously mix the material prior to discharge to a conveyor system.

- A discharge conveyor, with the ability to swivel and deliver the material to a paving equipment hopper while allowing the MTV to operate from an adjacent lane.

- A paver insert hopper with a minimum capacity of 18 tons which can be inserted into conventional paving equipment hoppers. Other pavers approved by the department may be used without an insert.

When a malfunction occurs in the MTV during laydown operations, work may continue for the balance of that day on any course other than the final wearing course. When an MTV malfunctions during final wearing course paving operations, plant operations shall be immediately discontinued and shall not resume until the MTV malfunctions have been remedied. Wearing course materials in transit may be placed. This procedure in no way excuses the contractor from meeting contract specifications.

Due to the weight of the loaded MTV, the following restrictions shall apply at bridge crossings:

- The MTV shall be as near empty as possible prior to crossing a bridge.

- The MTV shall be moved across a bridge without any other vehicles being on the bridge.

- The MTV shall be moved on a bridge only within the limits of the travel lanes and shall not be moved on the shoulders of the bridge.

- The MTV shall move at a speed no greater than 5 miles per hour without acceleration or deceleration when crossing a bridge.

The project engineer reserves the right to either not require the MTV on small projects (i.e., bridge tie-ins) or remove the MTV in situations where it is suspected that its use is damaging the existing underlying pavement structure.

Traffic Control - All signing and traffic control devices shall be in accordance with the latest edition of the *Manual on Uniform Traffic Control Devices* (MUTCD) and the plans and shall be installed and maintained properly. If needed, flaggers shall be used in sufficient number and adequately equipped to control traffic and protect the compacted mat until it has sufficiently hardened (160° F is a benchmark temperature). The paving inspector shall check all signs and traffic control devices daily and document this inspection on the Project Diary, in accordance with EDSM III.5.1.8. Any signs or traffic control devices, which are not properly installed, clean, legible, damaged or obscured from view, shall be corrected. If the deficiency in signing or traffic control violates the plans or MUTCD or creates a serious hazard to the traveling public, construction operations shall be discontinued until the deficiency is corrected.

Surface Preparation – Depending upon the type of base material on which the HMA is being placed, a different type of asphaltic material shall be applied to the existing surface. The different types of asphaltic materials, along with their applicable sections in the *Standard Specifications,* are:

1. Tack Coat – Section 504
2. Prime Coat – Section 505
3. Curing Membrane – Section 506.

Tack Coat is applied to existing hot-mix asphalt, asphaltic surface treatment or Portland cement concrete pavement surfaces.

Tack coat material shall be an undiluted modified asphalt emulsion Grade CRS-2P, CSS-1, SS-1, SS-1P or SS-1L complying with Section 1002.

Tack coat may not be applied on a wet surface or when the ambient air temperature is below 40° F.

The distributor used to apply the tack coat shall be certified. The surface to be tacked shall be swept and all edges of pavements shall be satisfactorily cleaned.

The rates of tack coat application are listed below. (Note that these rates may be raised or reduced as directed by the project engineer and are minimum rates of undiluted asphalt emulsion.)

Asphalt Tack Coat Application Rates	
Existing Surface	**Rate (gallons/sq yd)**
Bleeding Surface Treatment	0.02
Dry Surface Treatment	0.03
New Hot Mix	0.03
Old Hot Mix	0.07
Portland Cement Concrete	0.07
Friction Course	0.05
Cold Planed Surfaces	0.08

The minimum application temperature of the modified asphalt emulsions and emulsified asphalt Grade CRS-2P is 160° F and Grades CSS-1, SS-1, SS-1L and SS-1P is 70° F.

The contractor will be permitted to apply the tack coat one calendar day prior to the mixture laydown; however, when tack coat has been damaged by traffic pick-up or contaminated by dirt, dust or mud, the surface shall be cleaned and retacked prior to the mixture laydown at no direct pay. Tacked surfaces exposed to traffic for more than 24 hours or damaged due to inclement weather shall be retacked at nor direct pay.

Asphalt tack coat is not measured for payment.

Prime Coat is applied to crushed aggregate, stone and concrete base courses. Prime coat shall be cutback asphalt Grade MC-30, MC-70 or AEP Emulsified Asphalt complying with Section 1002. Prime coat shall not be applied on a wet surface or when ambient air temperature is less than 35° F in the shade.

The distributor used to apply the prime coat shall be certified. The surface to be primed shall be shaped to required grade, free from ruts, corrugations, segregated material, or other irregularities and shall be compacted to required density.

Prime coat shall extend 6 inches beyond the width of surfacing shown on the plans.

Listed below are prime coat application rates and temperatures for allowable prime coat materials.

Asphalt Prime Coat Application Rates and Temperatures				
Asphalt Grade	**Application Rate (gal/sq yd)**		**Application Temperature (°F)**	
	Minimum	**Maximum**	**Minimum**	**Maximum**
MC-30	0.25	0.30	60	120
MC-70	0.25	0.30	100	180
AEP	0.25	0.30	60	120

After the prime coat has been applied, it shall cure for a minimum of 24 hours before the surfacing is applied.

Asphalt prime coat is not measured for payment.

Curing Membrane is applied to the surface of cement or lime treated/stabilized materials. Curing membrane shall be emulsified asphalt or an emulsified petroleum resin (ERP-1) complying with Section 1002. Curing membrane shall not be applied when the temperature is below 35°F, unless otherwise permitted by the project engineer.

The distributor used to apply the curing membrane does not have to be certified. The surface to which curing membrane is to be applied shall be free from ruts, corrugations, loose material or other irregularities.

The curing membrane shall be applied immediately upon completion of final finishing of the final lift of the surface. **The curing membrane shall be uniformly applied at a minimum rate of 0.10 gallons per square yard of undiluted emulsified asphalt.** The ERP-1 curing membrane shall be uniformly applied at a minimum rate of 0.20 gallons per square yard of undiluted resin. The undiluted emulsified petroleum resin shall consist of 5 parts water and 1 part resin concentrate. The contractor shall place any additional applications required at no direct pay.

When emulsified asphalt is diluted with water and applied in multiple passes of the distributor, the total amount of asphalt material applied shall be increased so that the residual amount of asphalt material equals a minimum of 0.10 gallons per square yard.

When traffic is permitted on the applied surface, additional curing membrane shall be applied at intervals to protect and cure the surface at no direct pay.

Asphalt curing membrane is not measured for payment.

HMA Mixtures – All truckloads of HMA materials shall be accompanied by a properly completed haul ticket. No material shall be placed from a truck without a properly completed haul ticket. The inspector shall inspect the mixture in the truck, in the paver hopper and behind the paver.

If the material appears to be segregated in the truck, the inspector will determine if the degree of segregation is severe enough to warrant rejection. If the load is placed, the inspector is to sample the material for subsequent testing. If the material appears segregated in the truck, the inspector must check the mat carefully behind the paver. If segregation is apparent, the inspector is to notify the project engineer and the plant inspector. The inspector will reject future trucks showing segregation. If material does not appear segregated in trucks, but the mat exhibits segregation, the inspector will require the contractor to identify and correct the problem immediately. If the problem cannot be corrected, the contractor/producer shall discontinue operations for DOTD. Segregated areas of compacted HMA mat will be subject to department investigation for acceptability and may have to be removed and replaced at the contractor's expense.

Any material that is not properly coated, has lumps, or is contaminated will be rejected prior to placement. Lumps may be indicative of moisture problems or a dryer/drum that needs to be cleaned out. If the paving inspector observes this deficiency, the inspector is to notify the plant inspector. Operations shall be discontinued and the dryer/drum cleaned. The inspector is to sample mix that is not properly coated and perform a Ross Count (T 195). The inspector will also sample contaminated material. When sampling a material for future department investigation, the paving inspector must be certain to obtain a sample that is representative of the questionable material. For example, if the material is being rejected because of segregation, the segregated area is to be sampled.

If a load of HMA material is suspected of deficiencies, but the department allows it to be placed, the paving inspector will also sample the material for subsequent testing. The paving inspector will document the exact location where the deficient material was placed. Deficient material may require subsequent removal and replacement.

The paving inspector is also responsible for checking the temperature of the material in the trucks and in the paver hopper. The paving inspector will check the material in the truck and in the paver hopper for each truckload the temperature of which was recorded on the back of the haul ticket. If the HMA mix temperature is a problem or if conditions at the paving site warrant, this frequency will be increased to ensure that all material is within specification temperature requirements. The temperature of the material in the truck shall be within 25° F of the bottom limit of the job mix formula (JMF). If the temperature is outside this tolerance or exceeds the upper JMF temperature limit, it is out of specifications and shall not be placed. The paving inspector will record the job site temperature and rejected tonnage on the back of the haul ticket and void the ticket. The paving inspector will immediately notify the Certified Plant Inspector and check each subsequent truck until the material temperature is again within acceptable limits. The material temperature in the hopper will be recorded on the back of the haul ticket. The temperature of the mix going through the paver shall not be cooler than 250° F. In such cases, the temperature of the material and the tonnage discarded will be documented on the back of the haul ticket and the payment quantity adjusted.

In the case of polymer modified HMA materials, it may become necessary when the material is being dumped into the MTV to discard approximately 200 to 300 pounds of material. The contractor/producer shall dispose of this material outside the limits of the right-of-way. No deduction in lot tonnage totals shall be made for this material waste. However, the paving inspector is to continually monitor the truck dumping operation to assure minimal waste.

PAVING OPERATIONS

Coordination of Paving Operations with Production and Transport - One of the most important elements of successful HMA paving operations is the coordination of paving speed to plant production and hauling capacity. A start and stop operation will not produce a uniform mat and smooth riding surface. **A start and stop paving operation is specifically prohibited by the specifications.** The *Standard Specifications* require the contractor/producer to coordinate and manage plant production, transportation of HMA, and laydown operations to ensure reasonably continuous plant and paving operations with minimum idle time between loads. Delivery of the material to the paver must be at a uniform rate. There should be no waiting time between truckloads; nor should a large number of trucks be waiting to discharge into the paver. The correct speed for the paver is such that as one truck empties and pulls away, one truck is waiting to move into discharge position immediately. If sufficient hauling vehicles are not available to maintain a smooth, coordinated paving operation, the specifications authorize the discontinuance of operations or requirement of additional trucks.

Determination of Optimum Paver Speed Based on Truck Arrivals – In order to ensure a continuous paving operation, the inspector is to observe how often loaded trucks arrive at the jobsite. The inspector must also determine how many tons of material each truck is carrying. The number of tons in each truck will be found on the haul ticket. With this information, the inspector can determine the maximum speed at which the paver can operate without waiting between trucks.

To make this determination, the inspector will first compute the number of pounds of HMA required per linear foot of paving based on theoretical yield (plan quantity) and lane width. By dividing this figure into the number of pounds carried by each truck, the inspector can determine the linear feet to be covered by each truckload. The linear feet of paving per truckload divided by the time interval between truck arrivals will yield the maximum paver speed that will coordinate hauling capacity and laydown.

These calculations are represented by the following formulas:

$$S = \frac{D}{R}$$

Where:

$$D = \frac{P}{\left(\frac{W}{9}\right) \text{ x T x C}}$$

$$R = \frac{60}{\left(\frac{H}{L}\right)}$$

And,

S = calculated paving speed (based on truck arrival)
D = distance covered (linear feet) by one truck
R = truck arrival rate
P = truck load in pounds
W = width of mat in feet
9 = a constant, used to convert from sq ft to sq yd
T = mat thickness in inches
C = HMA weight constant, (115 lb/sq yd/inch of depth)
60 = a constant, used to convert hours to minutes
H = plant production rate (tons per hour)
L = truck capacity (tons)

Example:

The trucks on a project carry an average of 20 tons (P = 40,000 pounds). The paver is laying a mat width of 12 feet (W) and 1.5 inches thick (T). Trucks are arriving at the paving train approximately every 10 minutes (R).

Solving for the paver speed (S) when rate is known.

$$S = \frac{D}{R}$$

$$D = \frac{P}{\left(\frac{W}{9}\right) x\ T\ x\ C}$$

$$D = \frac{40{,}000}{\left(\frac{12}{9}\right) x\ 1.5\ x\ 115}$$

$$D = \frac{40{,}000}{1.333\ x\ 172.5}$$

$$D = \frac{40{,}000}{229.9425}$$

$$D = 173.95$$

$$S = \frac{173.95}{10}$$

$$S = 17 \text{ feet per minute}$$

The time required for the truck exchange at the paver should be taken into account in establishing maximum paver speed. If one minute is used for the empty truck to pull out and the next loaded truck to be positioned and picked up by the MTV with a rate of 10 minutes, the 20-ton trucks would need to be unloaded in nine minutes (10 minutes – 1 minute = 9 minutes).

Therefore, the paver should travel 19 feet per minute to accommodate the truck exchange.

$$S = \frac{D}{R}$$

$$S = \frac{173.95}{9}$$

S = 19 feet per minute

These computations are based on continuous and regular truck arrivals. If a contractor cannot maintain continuous material delivery, operations must be altered. The contractor will be required to either reduce paver speed to match hauling capacity and plant production or to supply additional trucks to maintain a continuous material supply to the paver.

Determination of Optimum Paver Speed Based on Plant Production – Since the rate of plant production (H) has a direct influence on the supply of the material to the project, the paving inspector can anticipate how often trucks will arrive at the jobsite by determining plant production from the job mix formula or from information on production supplied by the QC technician.

Example:

Anticipated plant production is 250 tons per hour and each truck will transport 20 tons.

Solving for rate (R):

R = trucks needs per hour

$$R = \frac{60}{\left(\frac{H}{L}\right)}$$

$$R = \frac{60}{\left(\frac{250}{20}\right)}$$

R = 4.8 = 5 minutes per truck

Therefore, the rate (R) of loading at the plant is 5 minutes per truck and the minimum number of trucks to transport 250 tons per hour of material from the plant will be 12 trucks per hour.

It is good practice to have one (or two) more than the minimum number of trucks needed to handle plant production, so that there can always be a truck at the plant waiting to load and a truck at the jobsite waiting to unload. The haul time and plant production rate will determine the number of trucks needed for a continuous operation. Haul time is round trip travel time between the plant and the paver, plus waiting, loading, covering and unloading times.

For Example:

Assume for the plant and production rate shown in the example that the following adjustments will have to be considered to ensure that there is a continuous flow of trucks to the paver at the jobsite.

Roundtrip travel time	=	60	minutes
Waiting time (plant)	=	10	
Loading time (plant)	=	5	
Waiting time (tarp/ticket)	=	5	
Unloading time (roadway)	=	5	
	=	90	minutes total

To compute the number of 20-ton trucks required to keep a loaded truck at the paver to unload every 10 minutes when the production rate is 250 tons per hour, divide the total haul time (90 minutes) by the rate (R = 5 minutes) used in the loading a truck at the plant.

$$\frac{90}{5} = 18 \text{ trucks}$$

Note that a minimum of 18 trucks hauling material to the jobsite meets the demands of plant production and haul time by providing a complete round of trucks leaving the plant every 90 minutes, each truck at an interval or rate (R) of 5 minutes. Any significant change in the number of trucks would necessitate a change in plant production or truckload size to balance the operation. Also, if plant production is altered, the number of trucks needed for the delivery of material being produced will need to be adjusted. However, to ensure continuous operations with minimum interruption of production or laydown with a truck always waiting at the plant to load, one or two trucks should be added. In addition, as travel time from the plant to the jobsite changes (e.g. rush hour), the number of trucks needed for continuous delivery will require adjustment.

NOTE

If the number of trucks determined by this calculation is not a whole number (e.g., 18.3 trucks), it is always necessary to round **up**. If 18.3 trucks are determined by calculation, 18 trucks are insufficient; 19 haul trucks are needed.

At the beginning of a day's operation, several trucks may arrive at the paving site before the paver is ready to begin laying HMA. When this occurs, beginning paver speed should still be based on anticipated truck arrivals throughout the day, calculated from plant production rate, hauling capacity and the number of available trucks. Paver speed should not be increased in an effort to quickly discharge the waiting trucks. If there are many trucks waiting to unload, paver speed, however, may be increased for the first few trucks only, then decreased for subsequent loads, until trucks arrive at regular intervals. The discontinuance of either paver or plant operations is to be avoided. If rapidly cooling material or a similar problem exists, consideration should be given to adjusting paver speed without upsetting the smooth, continuous delivery of material to the paving site.

YIELD

Theoretical Yield – The estimated quantity of HMA shown on the plans is the amount that should be used on the project based on a mixture that weighs 115 pounds per square yard per inch of thickness. If the project is constructed in accordance with the dimension and mat thickness shown on the plans, this plan quantity should be accurate, except for mixtures whose unit weight is different from 115 pounds per square yard per inch of thickness. If less HMA is used than called for by the plans, the mat will probably, on the average, be too thin.

If more HMA is used than called for by the plans, the mat will probably, on the average, be too thick. Additionally, a cost overrun will result. Failure to keep the actual quantity of HMA used fairly close to plan quantity may require a plan change. If extra material is needed for minor adjustments due to field conditions, it is imperative that current departmental policy for overruns be strictly followed. HMA overruns are allowed up to five percent.

The plan quantity is always calculated on HMA material weighing 115 lb/sq yd/inch thickness. However, some aggregates such as sandstone or slag will cause the unit weight of the mixture to differ from the standard 115 lb/sq yd/inch value.

To take this weight difference into account, the department has established weight-volume adjustment factors to determine the theoretical yield of an HMA material with a theoretical maximum specific gravity (G_{mm}) outside of 2.400 – 2.540. These factors (from the *Standard Specifications)* are shown in the table on the next page.

Theoretical Maximum Specific Gravity, (G_{mm}) (AASHTO T 209)	Adjustment Factor (F)
2.340 – 2.360	1.02
2.361 – 2.399	1.01
2.400 – 2.540	1.00
2.541 – 2.570	0.99
2.571 – 2.590	0.98

The adjustment factor (F) for mixtures with maximum theoretical specific gravities (G_{mm}) less than 2.340 or more than 2.590 will be determined by the following formulas:

Theoretical Maximum Gravity (G_{mm}) less than 2.340:

$$F = \frac{2.400}{S}$$

Theoretical Maximum Gravity (G_{mm}) more than 2.590:

$$F = \frac{2.540}{S}$$

Where:

F = quantity adjustment factor
S = theoretical maximum specific gravity (G_{mm}) on JMF

Example,

Theoretical maximum specific gravity is 2.320.

$$F = \frac{2.400}{2.320}$$

F = 1.0345 = 1.03

The theoretical maximum specific gravity (G_{mm}) can be found on the approved job mix formula.

For HMA materials with an adjustment factor other than 1.00, the theoretical yield of the mixture may be determined by dividing the theoretical yield based on 115 lb/sq yd/inch thickness by the applicable adjustment factor.

For example:

If the material being placed has a maximum theoretical gravity (G_{mm}) of 2.390, the factor of 1.01 will apply. Assume the material is being placed in a 2.0-inch lift.

$$\text{Theoretical Yield} = 115 \times T$$

$$\text{Theoretical Yield} = 115 \times 2.0 = 230 \text{ lb/sq yd}$$

$$\text{Adjustment Theoretical Yield} = \frac{\text{Theoretical Yield}}{\text{Adjustment Factor}}$$

$$\text{Adjustment Theoretical Yield} = \frac{230 \text{ lb / sq yd / inch}}{1.01}$$

$$\text{Adjusted Theoretical Yield} = 227.7 \text{ lb/sq yd}$$

Therefore, a mixture with a maximum theoretical gravity (G_{mm}) of 2.390 would require 2.3 less pounds (230 – 227.7 = 2.3) of HMA material per square yard for the same volume (2.0 inches thick) as a mixture with a maximum theoretical specific gravity (G_{mm}) between 2.400 and 2.540, inclusive.

These factors are used to adjust pay quantities, which are based on actual tonnage used, documented on haul tickets. If plan quantity for a project is 11,620 tons and the material placed has a theoretical gravity of 2.390 (factor 1.01), 11,504.950 tons of this material would be needed to occupy the same volume as a mixture with a maximum theoretical gravity (G_{mm}) of 2.400 – 2.540 (factor 1.00). Therefore, the target tonnage for this project would be 11,504.950 tons. Assuming that this target tonnage is the tonnage used on the project as documented on the haul tickets to calculate payment tonnage, multiply the tons used by the factor 1.01.

$$11{,}504.950 \times 1.01 = 11{,}620.000 \text{ tons}$$

The contractor will be paid for 11,620 tons of material, which equals plan quantity. If the contractor were to place plan quantity (11,620 tons), the mat would be too thick. Therefore, the factors must be applied when doing yield calculations, to be certain that the correct amount of material is being placed.

Actual Yield – Actual yield is the actual amount of HMA material placed in terms of pounds per square yard. It is the responsibility of the Certified Paving Inspector to maintain a constant check on actual yield during paving operations to ensure that at the end of the project, actual yield and theoretical yield will closely match. Actual yield should be checked and compared to the theoretical yield several times during a paving day, at the end of a lot, and at the end of the project. Since mat thickness is averaged and not exact, actual yield may vary slightly from theoretical yield on an individual truck or even for several truckloads. However, it should never run consistently over or under theoretical yield. If actual yield is consistently over or under theoretical yield, something is not correct with the paver screed settings. The contractor will then be required to identify and correct the problem, or the project will not conform to the plans.

The formula for computing actual yield is:

$$\text{Actual Yield} = \frac{\text{Tons Used x 2000}}{\text{Square Yards of Pavement}}$$

JOINT CONSTRUCTION

All pavement joints shall be constructed according to the requirements of the specifications. They will be inspected by the department’s inspectors for satisfactory compliance to the department standards in accordance with the procedures described in this manual.

Transverse Joints – A transverse joint must be formed whenever paving operations are discontinued long enough for the temperature of the HMA material being placed to fall more than 50° F from the lower limit of the JMF. This includes the interruption of paving operations at the end of the day. Equipment malfunctions, plant problems, or weather conditions can also cause an interruption of the paving operations, which will require construction of a transverse joint.

When more than one lift of HMA is being placed, transverse joints in succeeding lifts must be offset by at least two feet. Therefore, it is important for the inspector to record the exact station of each transverse joint in a field book. It will then be possible to ensure that transverse joints in succeeding lifts do not violate this specification requirement.

After a temporary tapered tie-in is formed and compacted over a bond breaker (e.g., kraft paper or lumber) between the new mat and the existing grade, the inspector will check that there is no bump at the point where the taper meets the existing pavement surface. An abrupt change in grade would be a hazard to the traveling public.

When it is time to resume paving operations, the tapered area of the HMA material and the bond breaker is removed to a vertical mat edge. The inspector will then check the vertical face at several points across the paving strip to be certain it is vertical and at plan thickness. The inspector must also visually inspect the pavement as it approaches the joint. If the pavement appears to slope downward toward the joint, the inspector should use a stringline or straightedge to identify the point at which the mat begins to deviate from plan grade. The contractor shall then be required to cut the mat back to this point and remove the area of the mat that deviates from grade. The joint must be made at a point where there will be no dip in the mat. If there is no apparent deviation from grade as the mat approaches the joint, the inspector will check the area with a ten-foot static straightedge. The straightedge is to be placed parallel to the centerline at several points across the paving strip. If there are any deviations greater than 1/8 inch, the mat shall be cut back beyond the deviations. After the inspector has approved the location and vertical cut of the joint, the vertical face shall be coated with tack.

The inspector is to be certain that there is sufficient fluff and that the screed is positioned properly before allowing HMA material placement to begin. The inspector should get down eye level with the screed and check the angle the screed makes with the mat. The screed should form a slight upward angle with the mat, similar to the screed position during routine paving. If the screed is pointed downward, the screed will move down when the paver pulls forward. This will result in a too thin mat and a depression at the joint (a dip). If the screed is pointed too far upward, the screed will move up as the paver pulls away. This will result in a too thick mat and a bump at the joint. To ensure adequate fluff, the screed should rest on shims that are 15 to 25 percent of plan thickness (depending on mixture type; the adjustment is lower for coarser graded mixtures) placed on the already compacted mat or the screed should be set at a distance that is 15 to 25 percent of plan thickness above the surface of the mat.

The screed should also be checked for proper crowning. If no crown is specified, then a stringline may be used along the width of the screed to ensure that no crown is set.

After placing material to form the transverse joint, the paver shall move less than 100 feet down the paving lane and then stop until the inspector has approved the joint. If the joint is not satisfactory, material will have to be brought from the paver to correct the joint.

Transverse Joint Inspection for Approval – The last task of the paving inspector when a transverse joint has been made is to inspect the joint and give it final approval after compaction. If the joint is not satisfactory, the inspector must require the contractor to correct the area.

The inspector will visually inspect the joint longitudinally and transversely to determine if there are any apparent deviations in the area. The inspector will then place a ten-foot static straightedge at several locations across the joint location and attempt to push a shim the thickness of the applicable specification deviation beneath the straightedge. If there are any variations greater than that allowed by Table 501-3 of the *Standard Specifications*, the area shall be corrected. The inspector may want to check the joint location further with a long stringline (40 to 50 feet) to determine its rideability. If there seems to be a pronounced deviation when checked in this manner, the ride will be affected and correction may be required.

If the transverse joint does not meet specification requirements, the contractor shall correct it before the paving operation can proceed. Only the minimum amount of handwork required to correct the deficiency will be allowed and only the affected area shall be worked. This handwork must also be completed so that the area can be recompacted before the mat surface has cooled beyond the point where compaction cannot be achieved. If the deviation at the joint is excessive (i.e., beyond that which can be satisfactorily repaired with a minimum amount of handwork) the contactor will be required to completely remove the material placed and reconstruct the joint with the paver. This may have to be done at a later date. Excessive time delay can cause a large number of trucks to accumulate in front of the paver.

After any required corrections have been completed and the area recompacted, the inspector must recheck the joint to ensure that the corrective action has met all department surface finish requirements and that the surface texture of the corrected area is acceptable. If the inspector is still unable to approve the joint, the contractor must take additional corrective measures.

Longitudinal Joints – Department specifications stipulate that, during the construction of a longitudinal joint, no material shall be scattered loosely over the uncompacted mat. The overlapped material shall be pushed back to form a vertical edge above the joint. The vertical edge shall then be compacted by rolling to form a smooth, sealed joint. Longitudinal joints in one layer shall offset those in the layer below by approximately 3 inches; however, the joint in the top layer shall be offset 3 inches to 6 inches from the centerline of pavement if the roadway comprises two lanes of width, or offset 3 inches to 6 inches from lane lines if the roadway is more than two lanes. Tack coat shall be applied to longitudinal joints prior to placing an adjacent HMA mat.

Coarse aggregate shall not be raked from the HMA mixture at the joint. Excess material or spillage shall not be pushed onto the uncompacted mat. If workers cast the overlap onto the uncompacted mat, this material will be segregated and will not bond properly in the mat. Such material will ravel under traffic. If this occurs, the inspector must require that the material be removed from the fresh mat before the roller approaches the area.

After compaction, a properly constructed longitudinal joint should not be high or low when compared to the adjacent mat. There should be no rough material at the joint location. The joint must be properly sealed. There can be no opening allowed between the mats. The joint should not overlap onto the previously compacted mat. After compaction, the inspector must check the joint for all points applicable to the transverse joints. The inspector should also place a 10-foot static straightedge across the joint, transverse to the centerline. If there is any deviation greater than the transverse surface tolerance applicable to that course listed in Table 501-3 of the *Standard Specifications* when the joint is checked with the 10-foot static straightedge, corrective action will be required. Checking the joint with a 10-foot static straightedge is effective on a tangent slope, but will not work on a two-lane roadway with center crown. For a roadway with center crown, the inspector will place a ten-foot static straightedge across the joint with approximately one foot resting on the new mat. If the fluff was not adequate, there will be a dip at the joint and the paver shall be adjusted.

On final wearing course, construction under traffic with pavement layers of 2.0 inches compacted thickness or less, the contractor will be permitted to pave one travel lane for a full day. The contractor shall pave the adjacent travel lane the next workday. When pavement layers are greater than 2.0 inches compacted thickness, the contractor shall place approximately ½ of each day's production in one lane and the remainder in the adjacent lane.

SEGREGATION

As previously stated, Subsection 503.10 of the *Standard Specifications* requires the use of a material transfer vehicle (MTV) when placing the final two lifts of HMA on the roadway travel lanes. The three main objectives in requiring the MTV are to reduce HMA segregation, improve surface smoothness, and promote continuous, non-stop paving. However, HMA materials may be placed without the use of the MTV when placing base course mixtures, leveling, and shoulders. In any case, the paving inspector should continually monitor the finished mat for any segregated area.

When paving without an MTV (dumping HMA directly into the paver hopper from the haul truck), proper truck exchange is critical to the production of a smooth, uniform mat. The truck should never bump the paver and should not rest on the paver hopper. Material should not be dumped or spilled in front of the paver. The material should be dumped into the paver in a large mass to prevent segregation.

Segregated areas of the mat will have a different look than the rest of the roadway surface. These areas will be more open-textured. The size of these areas will vary depending on the severity of the cause. It is not uncommon for such open-textured area to be 30 feet long and the full width of the paver, although many of these areas are confined to 15-foot lengths and just the center two-thirds of the paver's width. These areas have a tendency to become more noticeable after being exposed to traffic for a day and can best be observed when the angle of reflective light is low (i.e., early morning or late evening) or just after a rainfall. Under these conditions, these open-textured areas remain wet and dark looking when compared to the drier surrounding areas.

Numerous investigations have identified the material at these truck end locations to be inferior in quality, possessing low asphalt content, with an extremely coarse gradation and a low roadway density. **The net result of these poor mix qualities is an area of roadway that will crack and/or ravel if used as a wearing course or be structurally deficient and subject to moisture damage if used as a binder or base course.** Beyond the poor mixture characteristics associated with these truck end segregations, a poor ride is most often the result. This poor ride is identified by dips at the same intervals previously described. These dips are due to either a screed settling on the coarse mix during construction (i.e., a mixture with high air voids offers less resistance to the screed) or the dips develop later under traffic, when these high-void areas which have low initial density are compacted more than the well-compacted areas immediately adjacent.

Truck end segregation is caused by the coarse aggregate fractions separating from the fine aggregate fractions either in the production, transport or laydown processes. In severe cases, this separation can be observed at the plant when noticeable roll-down of the coarse aggregate occurs toward the sides, the tailgate and the cab area of the haul unit. Such roll-down segregation results in a truck end in one or more of the following ways.

- The segregated roll-down material at the tailgate is fed onto an empty slat conveyor and fed back to the paver augers as segregated material, causing a truck end.

- The segregated roll-down material on the sides of the haul truck is fed into the wings of the paver hopper. When these wings are dumped (i.e., the material in the wings is fed to the slat feeder), this segregated roll-down material will cause a truck end.

- The segregated roll-down material at the cab end of the truck (which is the last to be fed from the truck) will roll down the entire length of the bed, and if fed by itself to the augers, will cause a truck end.

Even though no significant roll-down may be noticeable at the plant, truck end segregation may still occur due to one or both of the following reasons.

- During the last part of the truck unloading process, when the bed is being completely raised, material (which had not previously been observed to have been segregated) will become segregated as it rolls down the full length of the truck bed toward the paver hopper. This material, if fed alone to the augers, will cause a truck end.

- Material that accumulates in the wings of the hopper will most probably cause a truck end segregation area due either to the fact that the material that rolls into the wings is segregated to begin with or the temperature of the material, when the wings are dumped, is cool enough to permit segregation to occur (temperature segregation). Temperature segregation occurs when material going through the hopper at varying temperatures (i.e., material on the sides of the haul units will be cooler than the interior of the HMA mass) is placed producing inconsistent densities, transversely and longitudinally down the roadway. Varying density will lead to premature raveling and pavement failure.

Regardless of where the segregation is first observed, truck end segregation areas on the roadway are to be eliminated or minimized to the best degree possible. It is an important point to remember that the handling processes (e.g., coated in a dryer/drum, conveyed into a surge/storage silo, emptied into a large trailer truck and dumped onto an empty slat feeder) to which the material is exposed are causing segregation. It is an equally important point to know that some well-graded and well-coated mixes do not segregate given an identical handling process. Consequently, all attempts to eliminate or effectively minimize truck end segregation have not been taken until the contractor/producer has tried one or more mixture, process, and handling change.

The following steps should be taken whenever segregation is observed:

- Paver wings should not be dumped unless at the end of the paving day.

- Haul trucks should be loaded with the minimum of three drops, the last of which shall be in the middle of the bed. It is the intent of this loading procedure to first load as close to the tailgate and cab areas as possible to minimize roll-down and then complete the load in the middle of the bed.

- During the exchange of trucks at the paver (when no MTV is required), the level of material remaining in the paver hopper should not drop so low as to expose the hopper feed slats. Keeping the slat feeders covered with material will aid the mixing of whatever roll-down material exists with nonsegregated material before it is fed to the paver augers.

- The paver augers should be run at minimum revolution to reduce segregation. Further, the level of material should be maintained to at least that of the auger shaft.

- Any segregated areas in the pavement that occur at regular intervals must be eliminated or effectively minimized. The paving inspector must be aware of the potential problem and maintain constant communication with the production and paving personnel when a problem exists. The project engineer will instruct the contractor/producer to correct problems associated with segregation.

PAVER OPERATION

The paver shall be operated at a consistent speed that will produce a smooth, uniformly textured pavement surface and create a continuous operation in conjunction with plant production and hauling capacity. The hopper is to be kept reasonably full at all times; the slat conveyors should never be uncovered. Cold, segregated material in the hopper wings shall not be dumped into the paver. The paving inspector will check the sensitivity of the electronic controls to ensure they are working properly.

If screed extensions are used, they must be heated and meet all screed requirements and produce the same quality surface as the screed. When auger extensions are required, they must extend to within one foot of the end of the screed. With approval, the use of an auger extension with screed extensions in excess of one foot on one side may be waived for transitions, taper sections and similar short sections.

ROLLER OPERATION (COMPACTION)

It is critical to the life of an HMA pavement that it be properly compacted to develop the strength and proper aggregate interlock intended for the mixture. Sufficient compactive energy should also be applied so as to provide adequate design density. A properly compacted pavement will provide a smooth, sealed, impermeable riding surface.

It is the contractor's responsibility to establish a rolling pattern that will ensure optimum and consistent density. Almost every project or mixture type requires a varied rolling pattern. The ability of a mixture to be compacted will be affected by variables such as mixture temperature, aggregate gradation, type of aggregate and asphalt, ambient temperature, moisture content, and condition of the foundation on which the HMA is being placed and compacted.

Subsection 503.06 of the *Standard Specifications* states that all compaction equipment must be self-propelled and be capable of reversing without backlash. It is the contractor's responsibility to provide the number, type and size of rollers sufficient to compact the mixture to the specified density and surface smoothness. The contractor shall establish the number, type, size and rolling pattern on the first day of production for a particular mix design. Once established, the same protocol shall be maintained throughout production. If the pavement or mixture characteristics are changed during the project, the project engineer may require a revised protocol deemed appropriate for those changes. Compaction equipment shall be certified.

Steel wheel rollers may be either vibratory or nonvibratory. The wheels shall be true to round and equipped with suitable scraper and watering devices. **Vibratory rollers shall be designed for HMA compaction and shall have separate controls for frequency, amplitude and forward speed.** Non-vibrating steel wheel rollers shall be operated with drive wheels toward the paver. Vibratory rollers shall not be used on the first lift of HMA placed over asphalt treated drainage blanket. When HMA is placed on newly constructed cement or lime stabilized or treated layers, vibratory rollers shall not be used for at least 7 days after such stabilization or treatment.

Drawbar pull is defined as the horizontal force required to move the roller forward. The most efficient roller is that with the smallest drawbar pull. Rollers with large diameter drums have lower drawbar pull (rolling resistance), because they do not tend to penetrate as far into the mix to develop a contact area as a roller with smaller diameter drums.

When used, pneumatic tire rollers shall weigh a minimum of 11 tons when fully loaded with wet sand and shall be capable of exerting the full range of contact pressure from 60 to 80 psi. Tires shall have smooth tread, shall be the same size and ply rating, and shall be inflated to a uniform pressure not varying more than ±5 psi between tires. Wheels shall not wobble and shall be aligned so that tires of the other axle cover gaps between tires on one axle. Tires shall be equipped with scrapers to prevent adhesion to the HMA material. The pneumatic tire roller shall be kept 6 inches from unsupported edges of the paving strip; however, when an adjacent paving strip is down, the roller shall overlap the adjacent paving strip approximately 6 inches.

Rollers shall be operated at uniform speeds that will coordinate with paver speed and within the frequency setting so as to allow for proper drum impacts per linear foot. The more quickly a roller passes over a particular point in the new HMA surface, the less time the weight of the roller rests on that point. This in turn means that less compactive effort is applied to the mixture. As roller speed increases, the amount of density gain achieved with each roller pass decreases. The roller speed selected is dependent on a combination of the following factors:

- Paver speed
- Layer thickness
- Position of the roller in the roller train.

Typically static steel wheel rollers can operate at speeds of 2 to 5 miles per hour; pneumatic tire rollers typically run 2 to 7 miles per hour; vibratory roller can operate at speeds of 2 to 3 ½ miles per hour. Roller speed is also governed by the lateral displacement or tenderness of the HMA mix. If the mixture moves excessively under the roller, the speed of the compaction equipment should be reduced. As discussed earlier, roller speed affects the impact spacing for vibratory rollers. This spacing is important for controlling the amount of dynamic compaction energy applied to the pavement, as well as for obtaining the proper surface smoothness. At least 10 to 12 impacts per foot are needed to obtain adequate density and layer smoothness.

Rollers are not to reverse in the same location on subsequent passes. Reversal points of continuous passes should be skewed at an angle of approximately 45 degrees across the mat. Rollers should cross their reversal points when moving across the mat surface in order to smooth any dips or bumps caused by changing direction. When a vibratory roller is used for breakdown rolling, the vibrators must be turned off to compact joints or whenever the roller stops or changes direction.

The paving inspector will inspect the mat during compaction after the rollers have passed. If the mat tears, blisters, shoves, leaves indelible marks or displaces in any way beneath the roller, the paving inspector will require the contractor to adjust the operation so that the mat is not damaged. Deficiencies shall be corrected.

A mid-temperature *tender zone* has been identified for some Superpave mixes. The tender zone has been identified in temperature ranges of approximately 200° F to 240°F. The mixture can be satisfactorily compacted above this range or below this range, but the mixture is tender within the temperature range and cannot be adequately compacted. This is not true for all mixtures, but it has been observed for some Superpave deigned mixtures.

When a mixture is tender within the mid-temperature range, the preferred compaction method is to obtain density prior to cooling to the tender zone. This may require an additional breakdown roller or other changes in rolling techniques, but obtaining density prior to reaching the tender zone is preferable. In some cases, the mixture temperature may be increased slightly to provide more compaction time. However, excessive temperatures will magnify the problem. Another alternative is to use a vibratory steel wheel breakdown roller above the tender zone, followed by a rubber tire roller, which can be operated in the tender zone. The finish roller should be used after the mixture has cooled below the tender zone. This second method may not be satisfactory if the rubber tire roller picks up excessively.

Another possibility is to breakdown with a steel wheel roller above the tender zone, then complete the rolling process after the HMA has cooled to below the tender zone. This has been used on a number of projects, but problems may occur due to differential cooling of the mixture and due to excessive aggregate breakdown when rolling in the vibratory mode after the mixture has cooled to below 200° F. Therefore, vibratory rolling should not be used below 200° F.

If the tenderness problem yields a pavement with poor in-place density, or if the paving train length is excessively long due to the time required for the mixture to cool, adjustments to the mixture design must be made to eliminate, or at least reduce, the temperature tenderness zone. It is important that the paving crew working at the laydown site communicate with the plant personnel.

WEATHER LIMITATIONS

HMA materials shall not be applied on a wet surface or when the ambient temperature is below 50° F for wearing courses and 40° F for base and binder courses, except that material in transit, or a maximum of 50 tons in a surge bin or silo used as a surge bin at the time plant operation is discontinued may be placed; however, mixture placed shall perform satisfactorily and meet specification requirements. Inclement weather will be sufficient reason to terminate or not begin production.

When base course materials are placed in plan thicknesses of 2 ¾ inches or greater, these temperature limitations shall not apply, provided all other specification requirements are met. When a wearing course mixture is substituted for a binder course mixture, the temperature limitation for the binder course shall apply.